TPS BPM ELECTRONICS PERFORMANCE MEASUREMENT AND STATISTICS

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Abstract

The BPM electronics Libera Brilliance+ are developed for Taiwan Photon Source (TPS) which is a 3 GeV synchrotron light source constructed at NSRRC. This BPM electronics can accommodate four BPM modules with integrated FPGA-based hardware. The BPM was contracted in the 2nd quarter of 2011; I-Tech award the contract to provide BPM electronics for the TPS project. The first prototype had been delivered in August 2011 and performed the preliminary test to verify fundamental specifications; the rest units had been delivered respectively in December 2011 and June 2012. The acceptance test for all units had been completed during June to August of 2012. Performance of each unit are individually tested and measured. Statistics data will be summarized in this report.

INTRODUCTION

The TPS is a state-of-the-art synchrotron radiation facility featuring ultra-high photon brightness with extremely low emittance [1]. Civil constructions are expected to be finished in early 2013. Machine commissioning is scheduled in 2014. The TPS accelerator complex consists of a 150 MeV S-band linac, linac to booster transfer line (LTB), 0.15–3 GeV booster synchrotron, booster to storage ring transfer line (BTS), and 3 GeV storage ring. The storage ring has 24 DBA lattices cells with 6-fold symmetry configuration. This synchrotron machine requires beam position stability less than 1/10 beam size therefore the position measurement system is also required to achieve one hundred or even tens of nanometer resolution. TPS has decided to adopt Libera Brilliance+ [2] electronics for the position measurement. The new instrumentation has the satisfactory performance and diagnostic functionalities as well as provides interface for fast orbit feedback application [3]. The vast tests including current dependency, filling pattern dependency, temperature dependency, latency estimation, long-terrn and short-term stability have been done and summarized in this report. Statistics data will be summarized.

BPM SPEC AND FUNCTIONALITES

The TPS storage ring is divided into 24 cells and there are 7 BPMs per cell; the booster ring has six cells where each cell is equipped with 10 BPMs. The number of BPM modules installed in the BPM platform might vary due to various install consideration and future expansion. Therefore, the BPM platform is designed to accommodate maximum 4 BPM modules. The TPS acquire 76 BPM platforms in MicroTCA based form factor and 228 BPM processors modules for storage ring and booster synchrotron application exclude the spares or the extra BPM due to the later design change.

The conceptual functional block diagram of the BPM is shown in Fig. 1. It will be embedded with EPICS interface for control, monitor and configuration. The timing AMC module would provide functionalities of synchronization, trigger, interlock and post-mortem. The BPM platform should also accommodate the FPGA module for fast feedback application for the future expansion.

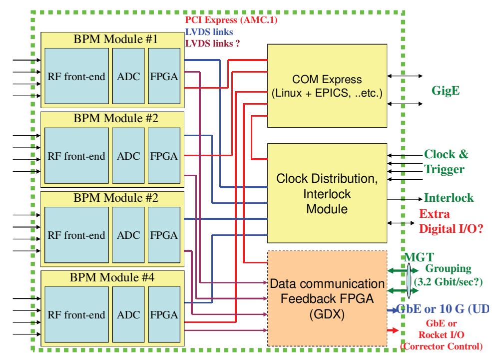

Figure 1: BPM platform functional block diagram.

The major specifications that the system must be fulfilled are also listed in Table 1.

Table 1: TPS BPM Performance Requirements

Parameters	Beam Charge/Current Range	Spec. (in rms)	Measured (in rms)
Single pass sensitivity and resolution	100 pC	< 1 mm	0.2 mm
Turn-by-turn resolution	0.5 mA	< 1 mm	0.15 mm
	10 mA	< 100 um	10 um
	500 mA	~ 1 um	1um
Resolution (10 Hz update rate)	0.5~10 mA	< 1000 nm	80 nm
	100~500 mA (14 dB range)	< 100 nm	20 nm
Resolution (10 KHz update rate)	100~500 mA	< 200 nm	100 nm
Beam current dependence	100~500 mA	< 1000 nm	200 nm
Filling pattern dependence	100~500 mA	< 1000 nm	200 nm
Temperature dependence		<1000 nm/^{o}C	~ 100 nm/^{o}C

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ACCEPTANCE TEST & SETUP

The first BPM prototype had been delivered in August 2011; the rest units had also been delivered respectively in December 2011 and June 2012. The delivered units had been performed functionality and performance test to ensure compliance with this specification in this August. The test environment setup is shown as Fig. 2.

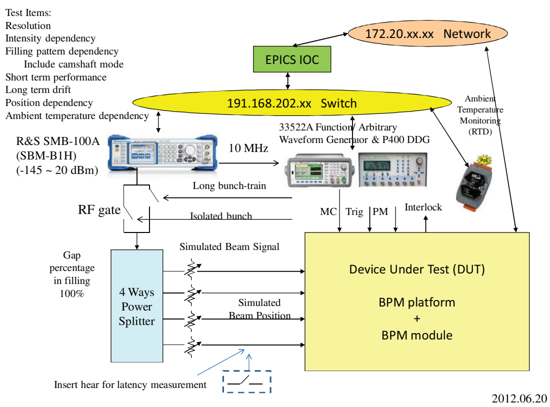

Figure 2: Set up for the acceptance test.

The BPM electronics will be sensitive to very small change (one part of 10000 or less) and many factors will affect the measurement. Since the beam splitter is sensitive from the ambient environment, we are using Polyethylene foam to perform thermal isolation. The vibration of cable will cause signal variation as well. The fixed solid cables are also essential to achieve nano-meter measurement performance. The setup for acceptance test is shown in Fig. 3.

Figure 3: Set up for the acceptance test.

The current dependency, filling pattern dependency, temperature dependency, latency, and short-terrn and long-term stability are verified and shown as the following sections.

FUNCTIONALITY TEST

To support 24/7/365 operation of the BPM electronics, functionalities like cold start, shutdown, housing, control system interface should meet the requirements.

Cold Start and Shutdown

All BPM platforms and BPM electronics have been performed cold and shutdown test. Only minor problems encounter. One platform had been re-installed and re-configured to resolve continuous program fail. One of 228 modules hardware had malfunction after three months operations. Reason of the fault is still in investigation.

EPICS Interface

The EPICS interfaces for all BPM platforms are tested. One defect is that some waveform records are empty (data is zeros) for first acquisition even external trigger is given. Besides, EPICS CA server crash had occasionally occurred and was reported to the vender. The upgrade to the EPICS IOC is foreseen in October 2012 roughly.

Housekeeping

The BPM platform provides power supply status monitoring, temperature monitoring, fan status monitoring and fan control. The status looks good from the system maintenance point of view.

Synchronization Stability

Synchronization is accomplished by internal PLL to lock to the revolution frequency and the stability is observed for 9 modules during 60 hours. The phase errors had never gone out of $\pm 1^{\circ}$ region and the PLL had always remained locked status.

RESOLUTION TEST

The BPM electronics provides several data flow including around 10 Hz slow data, 10 kHz fast data, turn by turn data, and ADC raw data. These different data flow resolutions would be estimated respectively as followings.

Slow Data

Figure 4 shows the histogram of horizontal and vertical position resolution distibution at power level around -10 dBm for 228 BPM modules. Most of these modules could achieve 20 nm resolution. Few mouldes could be over 50 nm which could be caused by ambient environment and will be further explained later. Fig. 5 shows resolution changes versus input power level variation. It can be observed that the resolutions don't worsen until the power level drops less than -50 dBm.

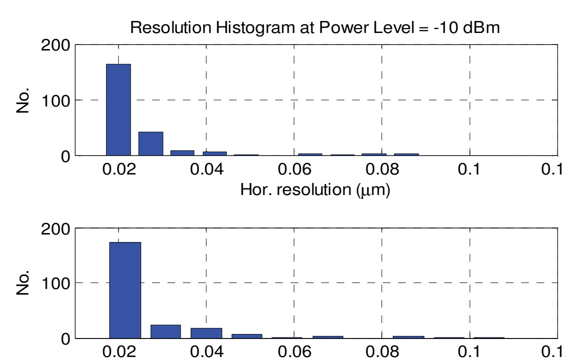

Figure 4: Histogram of horizontal and vertical position resolution distibution at power level around -10 dBm for 228 BPM modules.

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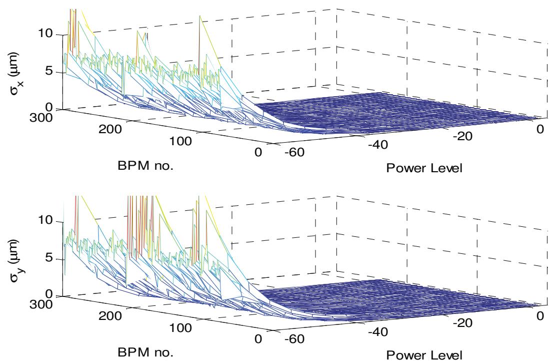
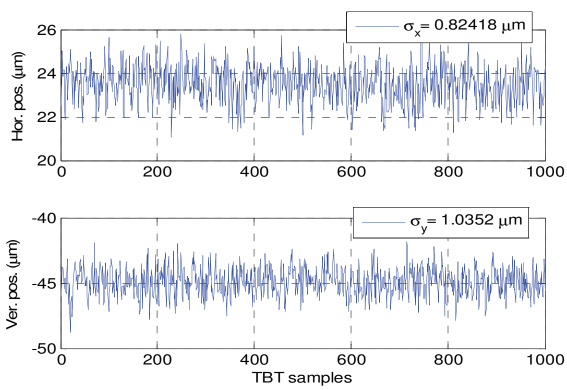


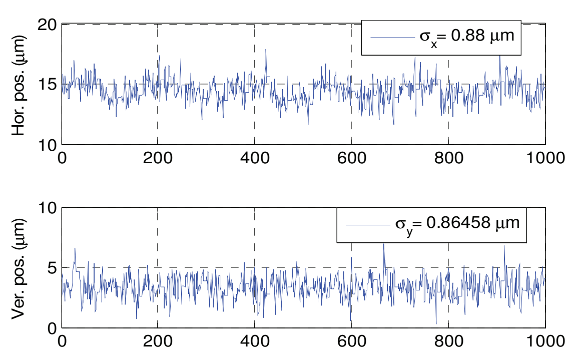
Figure 5: Position resolution versus power level change for 228 BPM modules.

Turn-by-turn Data

Turn-by-turn data resolution is evaluated between the two modes of switching and DSC (digital signal conditioning) on and off. There is no clear spike caused by analog switch input because new compensation method has been applied in this new platform. Both of the resolution could achieve around 1000 nm which meet the specification at 500 mA (~10 dBm). Fig. 6 shows the results. At lower current mode of 0.5 and 10 mA which power level decreases around -50 and -24 dBm, the resolutions are 150 and 10 um respectively, which also achieve the required performance.



(a) Switch and DSC Off



(b) Switch and DSC On

Figure 6: TBT data.

Fast Data

FA data resolution is around 100 nm and meets the specification which should be less than 200 nm as well. Fig. 7 shows the results.

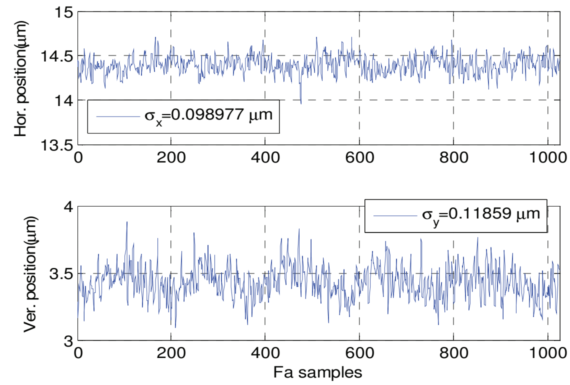


Figure 7: FA data.

BEAM CONDITIONS AND ENVIRONMENTAL EFFECTS TEST

The BPM electronics should be not sensitive but immune to the beam condition including beam current dependence, filling pattern, ambient temperature, mechanical vibration and etc. Efforts are summarized in the following paragraphs.

Current Dependency

TPS will be operated at top-up mode. Current dependency requires within 1 um variation for 100 mA ~ 500 mA range. Fig. 8 shows current dependency test result which is less than 200 nm for 40 dBm input power level changes.

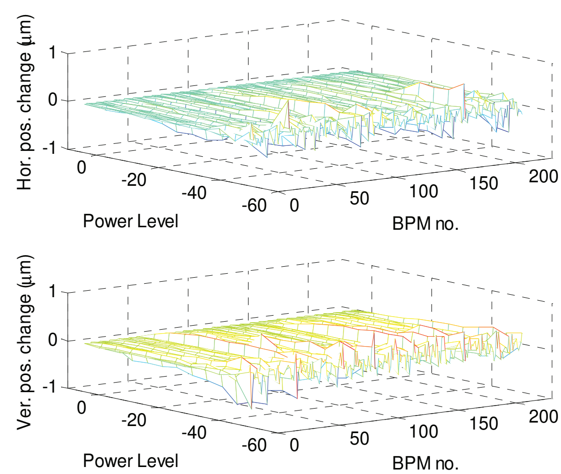


Figure 8: 228 BPMs current dependencies.

Filling Pattern Dependency

Figure 9 shows the filling pattern dependency versus different percentage of filling width with and without power compensation. Results clarified that both of

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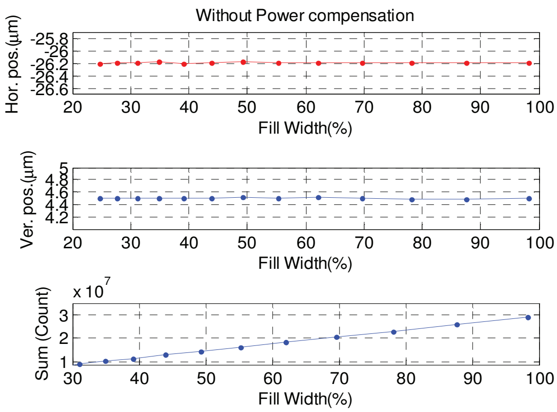
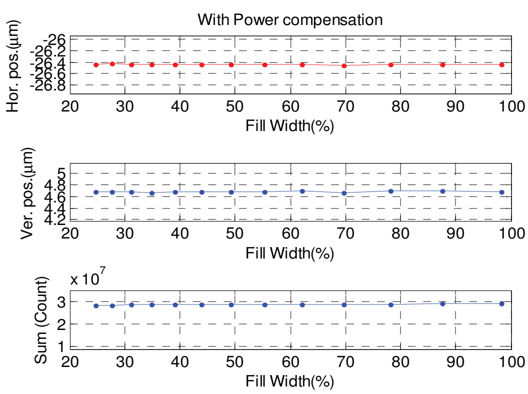
horizontal and vertical position changes are much less than 100 nm and can be ignored.



(a)



(b)

Figure 9: (a) Filling pattern dependency without power compensation. (b) With power compensation.

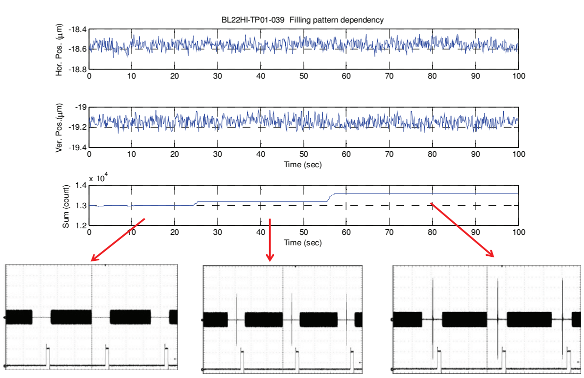


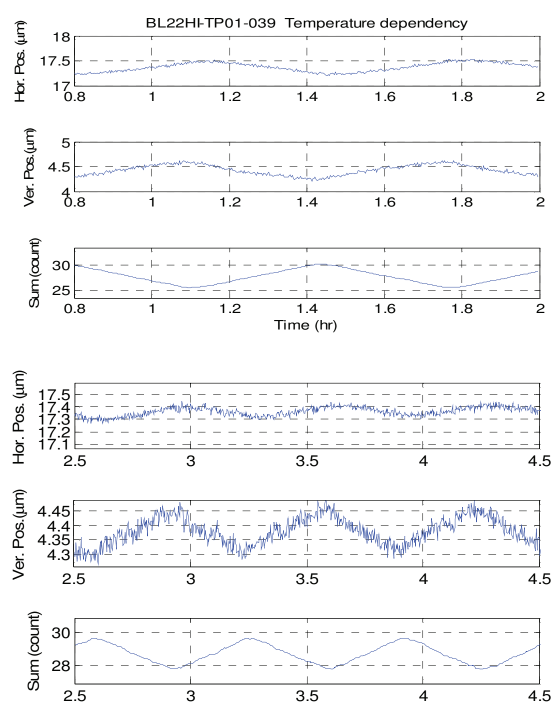
Figure 10: Position observation at camshaft mode filling pattern with/without isolated bunches.

The camshaft mode filling pattern is also tested as Fig 10. There were three modes observed: (1) without isolated bunches (2) with isolated bunches (3) with larger isolated bunches. It can be seen that sum value increasing reflects the switch of three modes while horizontal and vertical positions stay unchanged. It could be concluded that Camshaft mode fill pattern dependency almost can be ignored either.

Ambient Temperature Effects

To characterize drift due to ambient temperature variation, a BPM platform was put into an incubator chamber as Fig. 11 to do long term drift measurement. The incubator is set in soak mode from 25 to 30 degree, 27 to 29 and 28 to 29 degree in Celsius scale respectively. Fig. 12 shows the results of beam position changes versus temperature and it is observed that both of horizontal and vertical position changes are smaller than 100 nm/°C. Horizontal position fluctuation is observed to have 3 minutes delay compared to vertical one and it is inferred caused by thermal propagation delay on four ADCs.

Figure 11: Libera Brilliance+ platform put inside an incubator which provide precision temperature control in the range between 0~60 °C. Measurement is performed around 30°C.



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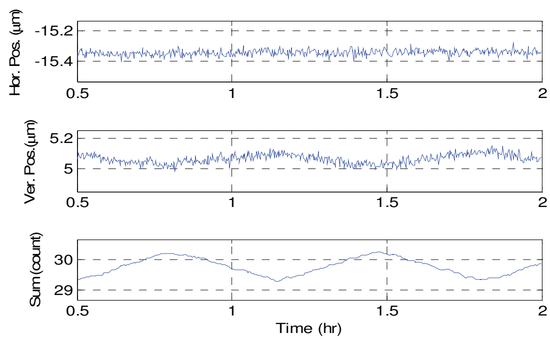
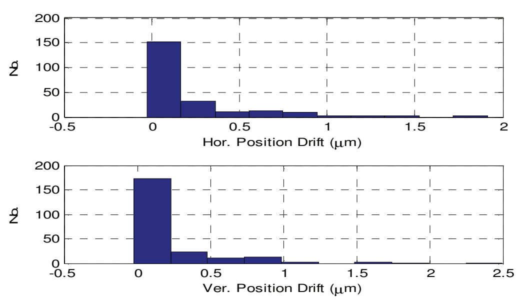


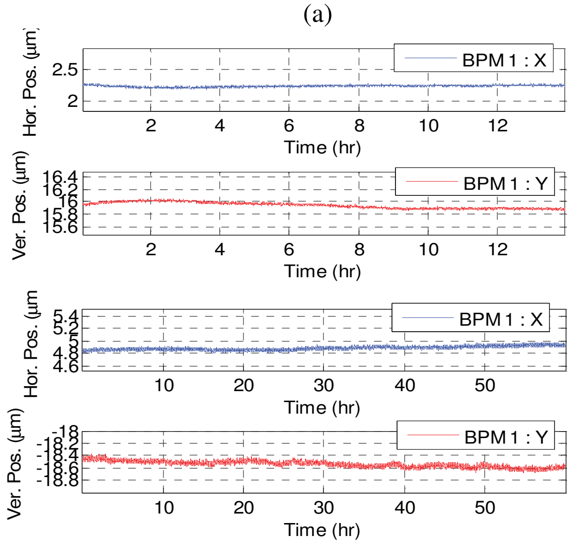
Figure 12: Temperature dependency around 100 nm/°C.

LONG-TERM AND SHORT-TERM STABILITY

Long-term and short-term position stabilities are studied as Fig. 13. Most of position drifts could be less than 500 nm within 30 minutes. It's observed that mechanic stability including fan vibration, air flow and cable sway quite effect BPM readins. In a steady and controlled condition, long-term position stability for 14 hours and 60 hours could be much less than 1 um as Fig. 13 (b)(c).



(a)



(b)

Figure 13: (a) Histogram of 30-minutes satbility for 228 BPM modules. (b) 14 hours and 60 hours stability observations for one BPM module.

LATENCY TIME

Interlock output is used to measure the FA latency for evaluating fast orbit feedback application. A steep orbit change implemented by controlled gating signal is applied to trigger interlock. The latency time calculated by the time difference between the input change and the interlock output is around 150 ± 50 us as Fig. 14. 100 us jitter is roughly equal to one FA sample period and the FA latency time is one to two FA sample period.

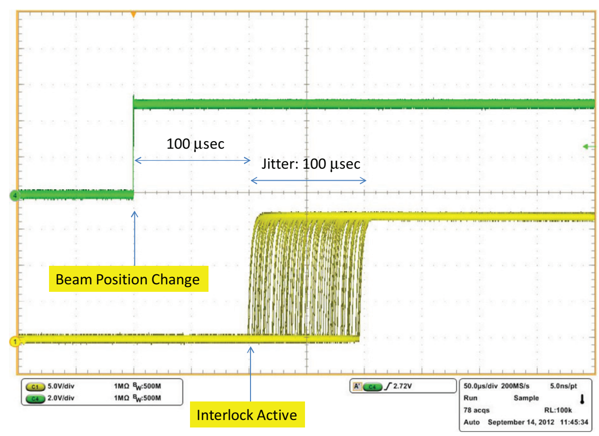


Figure 14: The time difference between input change and interlock output is around 150 ± 50 us.

SUMMARY

TPS BPM electronics factory acceptance test (FAT) had been completed in August. Each BPM platform and module had been individually tested and measured. Fundamental functionalities are passed. SA, FA and TBT resolution generally satisfy specification. Current, filling pattern and temperature dependency are also adequate. Mechanic stability is key issue beyond expectation when it requires nano-meter level stability. The FA latency time is around 150 ± 50 us.

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[2] Instrumentation Technologies: http://www.i-tech.si.
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